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Construction Managers' Perception for Sustainable Construction Contributing Factors: Analysis using Support Vector Machine

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***Abstract* –This paper investigates the construction managers' perception of sustainability contributing factors in construction. Respondents worked at 102 construction companies in the R. Macedonia and 102 in the Federation of Bosnia and Herzegovina (B&H). Using support vector machine, prediction models were designed. For classification of the target variable "familiarity with sustainable construction industry", 25 predictors were chosen. Depending on the validation method used, the accuracy of the B&H model was from 93.14% to 100%, and of the Macedonian model – from 91.18% to 94.12%. General conclusion is that construction managers should increase their knowledge about sustainability contributing factors.**

***Keywords* – Construction manager, Sustainability contributing factors, Construction, DTREG software, Support vector machine.**

1. Introduction

Sustainable construction means the application of the concept of sustainability in the construction [1], and it is a subset of sustainable development [2].

The sustainability and the construction as terms have been aggregated together to form a new complex concept [3]. There is not a definition that can cover all aspects of the sustainability in construction and most of them are highlighting the three construction sustainability aspects/pillars: environmental, social and economic [4]. The sustainable construction is concerned with issues related towards conceiving healthy environment with efficient use of materials and resources in total and establishing evaluation criteria based on the three sustainability pillars.

The environmental aspect is necessary because the construction is a significant contributor to the environmental pollution [5]. The social aspect of sustainability is much more difficult to grasp [4], but it is necessary because the structures affect the local community. They also affect the health of community inhabitants and construction industry workers. In many cases, performing the construction works are dangerous [6], so in the construction the social impact is mostly on the workforce.

The economic aspect of sustainability concerns the impact of construction on creating opportunities for jobs, the impact on increasing the value and return of investment and also, increasing the gross domestic product [7].

Sustainability aspects are in interaction; hence, in order for the construction to be sustainable, the different aspects of sustainability should be taken into account. Also, there is an interaction between the structures and their surroundings, so the construction industry can have an impact on the environment, the economic growth, and also on the local community and its inhabitants' health.

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1.1 Sustainability in construction

The core essence of sustainability in construction is based on the holistic approach that construction has an ultimate goal of restoring balance and harmony between built and natural environment, while enabling creation of dignifying human settlements and boost economic fairness.

Sustainable construction recognizes the need for accountability towards efficient resource use and decreasing adverse environmental effects and encompasses the society's needs for social and economic prosper [8]. It also increases the construction products quality [9], but the perception of the construction professionals is that the users' opinion about higher construction cost of sustainable building is an obstacle for sustainable development [10].

A framework proposed by [3] for evaluation of the sustainability of the construction processes in developing countries, aggregates the environmental limits, stakeholders, value system enablers and human needs, and takes into consideration their interconnections.

In [11] as dimensions of sustainability of building project are stated: economic, environmental, social and cultural. These goals move the projects away from traditional project management that is narrowly focused on cost, time and quality [12]. In an effort to address the issues of sustainability in the construction, certification schemes are developed which are gaining wide acceptance worldwide.

Introduction of sustainable innovations can provide considerable new opportunities for the companies [13]. According to LEED, as stated in [14] during the activities in construction it is necessary to undertake activities for pollution reduction.

Gama, Vieira and Coutinho [15] have pointed out that it is important to incorporate sustainability in all life-cycle phases of a building, especially during the construction phase. They have investigated the perception of sustainable practice during construction phase in Brazil and have shown that the sustainability of practices is unsatisfactory and they have also noted the increasing demand in the society regarding environmental aspects.

Chong et al., [16] have conducted a research in order to understand the perception of sustainability in the construction. It has been concluded that an effort that is persistent and broad-based is needed in order to successfully implement sustainability in the construction practice.

Regarding the above, it can be emphasized that construction in general has a crucial role in ensuring the sustainable development, so minimizing the negative impacts of sustainability aspects during construction processes has become an imperative. To achieve the goal of sustainable construction, for each individual construction project sustainable performance through its whole life cycle is necessary [17]. Therefore, many construction companies started to put emphasis on improving construction performance in terms of social and economic aspects and, also on technology of construction. Furthermore, construction equipment and machinery are selected and deployed in respect to the planet, profit and people that are "the triple bottom line of sustainability"- TBL [18], because the focus of organization on TBL is in positive relation with the organization' sustainability outcomes [19].

1.2 Construction managers' perception on sustainability aspects in construction

Managers' perception, as well the leaders' and employees' perceptions shape the climate of working environment in organizations [20]. Hence, the investigation of managers' perception on sustainability aspects and their implementation in the construction is of researches' special interest.

The study of [21] was focused on social aspects, with emphasize on the workforce. Their research of the construction managers' perception about health and safety has pointed out the factors that are the causes for the site accidents.

Assessing the perceptions about sustainability of organizations in [19] is concluded that organizations need to improve the link between environmental performance, the organizational purpose and the social responsibility in order to improve the organizational sustainability in a long term. They, also revealed that the perceptions about sustainability outcomes and protection of the environment are in significant and positive relationship.

Facilities managers' perceptions towards sustainability activities performance in their organizations is presented in [22]. The study's findings showed that in organizations with highest annual turnovers the perception of their sustainability management is more positive than the perception of lower annual turnover organizations.

Investigating the building managers' perception about the building accessibility, authors in [23] concluded that construction managers should increase their knowledge about the needs of universal design.

The investigation of Chendo [24] revealed that managers of the firms for sachet water have poor perception towards the disposal of waste and hygienic environment maintaining.

The project' stakeholders' perception on sustainable construction projects risks was researched in [12]. Authors stated that the discrepancy of the perceptions isn't significant.

The perceptions of the stuff and project managers' at the project site in engineering firms that are project based are investigated in [25]. Consequently, they proposed a model for the management of the implementation of a technology, which is perception-influenced model.

Construction managers' perception for implementation of sustainability during building process was investigated in [26]. It is concluded that construction managers need more information about sustainability aspects in building processes.

Khalfan et al., in [27] have investigated the perception of sustainability among construction contractors and concluded that they have positive perception regarding social and economic aspects. Several weaknesses have been identified regarding implementation of sustainable construction such as: client demand, associated costs of sustainable construction materials and practices and perceptions of employees and workers. On the other hand, the drivers of sustainable development and construction have been identified in the availability of environmentally friendly (green) material, financial incentives to clients and contractors, government policy for implementation and overall awareness within the construction.

Regarding the above mentioned, for implementing the sustainability concept in the construction, construction managers' knowledge and their understanding of sustainability is of essential importance. Therefore, this paper aims to assess the construction managers' perception about the sustainability aspects in the construction and their contributing factors.

A questionnaire was developed and polls were conducted in construction firms from B&H and from Macedonia. The results of the polls were analyzed with the predictive modelling software DTREG using support vector machine (SVM). Two models were built using the questions from the poll (one for B&H, and one for Macedonia) in order to predict (classify) the target variable "familiarity with the sustainable construction". It is concluded that construction managers' knowledge about construction sustainability contributing factors should be increased in order to create conditions for sustainable construction as a support to sustainable development.

2. Methodology

2.1 Survey

A questionnaire was developed to investigate the construction managers' perception of sustainability contributing factors for construction. Also, the purpose of the survey was to detect the body of knowledge that exists among the construction managers about the sustainability aspects in the construction.

The survey was conducted ”in-the-field“.

Questionnaire was distributed among construction managers that work at 102 construction companies in the Federation Bosnia and Herzegovina, and 102 construction companies in the R. of Macedonia. Only construction managers who had working experience on international projects were covered with the survey.

The questionnaire consisted of two main parts. The first part consisted of several basic questions about the size of the construction company, the experience of the questioned managers, their education and the type of the construction process.

The second part of questions was addressed to three sustainability aspects of the construction: social, economic and environment aspect.

Survey participants were asked to assess the questionnaire items on a 5-point Likert scale (from 1-completely disagree to 5-completely agree).

The collected answers from the questionnaire were used as input in the predictive modeling software DTREG using support vector machine (SVM). The target variable in the model was chosen to be "familiarity with sustainable construction" (question 7 - from the questionnaire that is given in Appendix). For building the model, 25 predictors (variables) from questions from the questionnaire were chosen, in order to obtain the most accurate predictive model. The list of predictors/questions is given in Table A (in Appendix).

The results from the modeling software will be discussed below. First, a short introduction is given to SVM, this relatively novel learning paradigm as predictive modeling concept.

2.2 Support Vector Machine

The Support Vector Machine (SVM) as a modeling method recently has shown better results than neural networks (NNs) and other statistic models on the benchmark problems, in most of the cases [28]. SVMs are specifically good at classification (pattern recognition), but also regression (function approximation) problems and other kind of modeling applications [29].

For the learning problem with SVM there is a nonlinear unknown dependent function y=f(X), where X is multidimensional vector X, and y is a scalar (or vector y if SVM is multiclass). The only information that is available is the training data-set, $S = \{(x_i, y_i) \in X \times Y \}, i = 1,..k$ where k is the number of the training data pairs. This definition is similar to the classical statistical paradigm, but there is important difference between the assumptions in the training with classical statistical modeling and SVM. In the classical statistical approach experimental data are being modeled by a set of functions which are linear in parameters and also the assumption for the data for most of real-life problems is that they have underlying joint normal probability distribution, i.e. Gaussian distribution. But for many contemporary real-life problems these assumptions turned out to be inappropriate, because most of the modern problems are highly dimensional and with an in-creasing dimensionality of the input (increasing number of independent variables), so that the linear problem will need exponentially increasing number of terms which becomes very hard for using. Also, the real-life data often have distribution laws which are very far from the normal distribution and this fact must be taken in consideration by the model builder in order to make an efficient learning algorithm for modeling non-Gaussian distributions. SVM models have been developed in order to overcome all aforementioned problems for standard contemporary data sets, which are in most of the cases high dimensional and for small training datasets [28].

In the SVM terminology, a predictor variable is called *attribute*. When SVM performs classification task and when given classes cannot be separated linearly in the original input space, then the SVM transforms the input space into higher dimensional space.

The transformed attribute in the new higher dimensional space is called *feature,* and this new space is called *feature space.* One row of values of the predictors is called a *vector.* The transformation in the new space can be done by using different nonlinear functions (kernel functions). After this transformation step, SVM finds a linear function (hyperplane) in the new feature space that separates the data into two categories. The goal of SVM modelling is to find the optimal hyperplane that separates the set of vectors in a way that cases with one category of the target variable are on one side of the plane, and cases with other category are on the other side. The vectors nearest to the hyperplane are called *support vectors.*

In the course of the successful training process, the learning machine (SVM) will be able to find the relationship between input X and output Y using the input data D in regression tasks, or, if it is classification task, it will find function which separates the data in the input space. The result of the learning process is, in fact, finding an approximation function f(x,w) which approximates the dependency between input and output in the regression task, or, if it is classification task that function will be separation function. This function is being constructed in such a way to minimize the error of the model [28].

3. Research, results and discussion

For modeling the data, SVM model for classification task is used from the modeling software DTREG [29, 30].

From the questionnaire, the question: ”familiarity with sustainable construction“ was used as target (dependent) variable and from the many questions from the questionnaire, 25 were selected for building the model in the way that the most accurate model is obtained (Table A in Appendix). The target variable has two categories (yes/no) answers and this variable has no numerical values. The variables that have categorical values are called categorical variables in DTREG software, those with numerical values are called continuous variables. SVM performs the task of classification for categorical target variables. SVM model performed classification of the data-set in these 2 categories. Two models were built for the dataset from the B&H questionnaire and for the Macedonian questionnaire.

Before starting to build the SVM model from the DTREG software, some options on the SVM model page should be chosen, in order to receive maximal accuracy of the model: for example: every offered kernel function (linear, polynomial, RBF or sigmoid) can be tried and select that which will give high accuracy; the type of the validation method should be also selected and the best possible range for the parameters C and Gamma for the SVM model should be adjusted.

For every category of answer for the predictors, DTREG software gives the results for the target variable: how many of the respondents who gave that answer (from 1-5), have answered with 1(yes), and how many with 2 (no) and also their percent from all rows from the input table (102). For example, for the predictor ”number of employees“ (Question 1 from Table A from the Appendix) which has 5 answers: 1 (less than 10), 2 (from 11 to 20), 3 (from 21 to 50), 4 (from 51 to 250) and 5 (more than 250), the results for the Macedonian case (Table 1.) are (in the first row of Table 1.): with answer 1 (less than 10 employees) answered 36, which is around 35 % of all 102 respondents, 28 of them answered with 1 (yes) for the target variable, which is 78 % of them, and 8 of them answered with 2 (no) (which is 22 % from them), and so on… The results are given in Table 1. for the Macedonian questionnaire and for the B&H questionnaire only for one predictor (Question 1 from Table A).

Table 1. Results for the target variable (1- yes and 2 – no) for every category of answer for one presented predictor: Question 1 – for the Macedonian questionnaire and for the B&H questionnaire

========= Summary of Categories ============						
- Macedonian questionnaire -						
--- Predictor ---			Target Variable: Question 7 --			
Question 1			1 (yes)		2 (no)	
36	35.29%	1	28	78%	8	22%
22	21.57%	2	20	91%	2	9%
25	24.51%	3	21	84%	4	16%
10	9.80%	4	8	80%	2	20%
9	8.82%	5	9	100%	0	0%
============ Summary of Categories ============						
- B&H questionnaire -						
--- Predictor ---			--- Target Variable: Question 7 ---			
Question 1			1 (yes)		2 (no)	
23	22.55%	2	19	83%	4	17%
35	34.31%	3	7	20%	28	80%
29	28.43%	4	16	55%	13	45%
15	14.71%	5	10	67%	5	33%

DTREG also computes the most characteristic values of every predictor with numerical value: minimal, maximal, mean value, and its standard deviation (given in Table 2. for the Macedonian and the B&H case).

Table 2. Minimal, maximal, mean value and its standard deviation for five predictors with numerical values for the Macedonian model and for the B&H model

Macedonian model					
======== Continuous Variables ============					
Variable	# Rows	Min.	Max.	Mean	Std. Dev.
1	102	1.00000	5.00000	2.35294	1.28831
2	102	1.00000	5.00000	3.63725	1.32687
5	101	1.00000	4.00000	2.09901	1.29359
6	102	1.00000	4.00000	2.96078	1.07486
8	102	1.00000	5.00000	4.1961	0.98995
B&H model					
========= Continuous Variables ======					
Variable	# Rows	Min.	Max.	Mean	Std. Dev.
1	102	2.00000	5.00000	3.35294	0.98665
2	102	1.00000	5.00000	2.87255	1.17716
5	102	2.00000	4.00000	3.65686	0.61827
6	102	1.00000	2.00000	1.04902	0.21591
8	102	1.00000	5.00000	2.86275	1.02937

For validation of the model, DTREG offers two types of validation methods: 1) random percent and 2) V-fold cross validation. When *”random percent“* method is selected then the software uses that percent of rows from all rows (102) for validation of the model and the rest percentage of the rows is used for training. For the B&H model, using ”random percent“ validation with 10 %, 13 %, 14 % and 16 %, the accuracy of the model was maximum 100 %. Using 20 % random validation, the accuracy was 95 %. Using 11-fold cross validation, the accuracy was 93.14 %.

For the Macedonian model, the best accuracy was obtained with random 17% validation when the accuracy was 94.12%, and with 10-fold cross validation the accuracy was 91.18 %. Table 3. shows the results for validation data for the accuracy of 94.12 % for the Macedonian case, and for the B&H with accuracy of 95 %.

DTREG also computes the importance of the predictors in the model. For the B&H model, DTREG reported 3 most important predictors (Table 4.), for the Macedonian model DTREG reported that all 25 predictors have equal importance.

Table 3. Validation data for the Macedonian model and for the B&H model

Macedonian model
-------- Validation Data --------
Total records = 17
Positive/Negative ratio = 0.2143
Accuracy = 94.12%
True positive (TP) = 2 (11.76%)
True negative (TN) = 14 (82.35%)
False positive (FP) = 0 (0.00%)
False negative (FN) = 1 (5.88%)
Sensitivity = 66.67%
Specificity = 100.00%
Geometric mean of sensitivity and specificity = 81.65%
Positive Predictive Value (PPV) = 100.00%
Negative Predictive Value (NPV) = 93.33%
Geometric mean of PPV and NPV = 96.61%
Precision = 100.00%
Recall = 66.67%
F-Measure = 0.8000
Area under ROC curve (AUC, C-Statistic) = 0.857143

B&H model
-------- Validation Data --------
Total records = 20
Positive/Negative ratio = 1.0000
Accuracy = 95.00%
True positive (TP) = 9 (45.00%)
True negative (TN) = 10 (50.00%)
False positive (FP) = 0 (0.00%)
False negative (FN) = 1 (5.00%)
Sensitivity = 90.00%
Specificity = 100.00%
Geometric mean of sensitivity and specificity = 94.87%
Positive Predictive Value (PPV) = 100.00%
Negative Predictive Value (NPV) = 90.91%
Geometric mean of PPV and NPV = 95.35%
Precision = 100.00%
Recall = 90.00%
F-Measure = 0.9474
Area under ROC curve (AUC, C-Statistic) = 0.950000

Table 4. Importance of the variables (predictors) for the B&H model

= Overall Importance of Variables =

Variable	Importance
Question 3	100.000
Question 4	92.308
Question 6	7.692

DTREG predicts (classifies) the values for the target variable and the predicted values from the validation data can be read from the DTREG Validation data row report file. Because in advance we do not know which predictive model will give the highest accuracy for the actual data, we should always try several predictive models and choose that which will give the best results. First, we tried the general regression neural network (GRNN) for modeling, but the highest accuracy was obtained with SVM.

The authors Zhao, Li and He in [31] used SVM and ANN to classify four carbon fiber fabrics and they received the best accuracy of the classification with ANN. The authors Pal and Mather, [32] have used SVM for classification of 7 land cover types in eastern England and they compared the results with another two classification methods: NN and Maximum likelihood Classifier. They received the best results with SVM with accuracy 87.9 %, with NN the accuracy was 85.1 % and with Maximum likelihood the accuracy was 82.9 %.

We should stress here that for obtaining the most accurate predictive model, the most relevant predictors for the target variable which is being predicted, should be selected.

For the B&H questionnaire the software reported 3 most important predictors that influence the construction managers who are acquainted with the term ‘sustainable construction industry’. The predictors are: previous job position/experience, previous education of construction managers and protection of the environment. Therefore, the regulation relevant for construction industry should put more emphasis on sustainability and its incorporation in that industry. In B&H regulation particular attention should be put on education of construction managers, their previous working experience and their licensing in the context of sustainability. Also, attention should be put to create construction working places that are sustainable working places with introducing of environmental friendly construction industry. Although the software reported that other predictors Table A in Appendix) are less influential to construction managers acquainted with the term ‘sustainable construction industry’, they should be, also given an attention in construction industry and relevant regulation.

In the Macedonian case, the software reported equal importance of all 25 predictors (Table A in Appendix). Therefore, all of them should be elaborated further and given a particular attention in Macedonian regulation relevant for managers in construction industry and for construction industry in general.

Regarding the above mentioned and having in mind that the surveyed construction managers had working experience on international projects, it could be said that other countries should also put more attention on sustainable construction industry contributing factors, managers’ knowledge about them, regulation and other issues relevant for sustainability in construction industry.

4. Conclusion

Construction managers play a vital role in integration and implementation of the environmental, social and economical aspects in construction. In this paper, data obtained from survey of construction managers in B&H and Macedonia has been analyzed using support vector machine (SVM) from the DTREG software package. Two models were created to analyze the construction managers' perception for the sustainability contributing factors to construction and to classify managers' familiarity with sustainable construction. The models were built from questionnaire done in Bosnia and Herzegovina and from questionnaire done in Macedonia.

Depending on the validation method used, the accuracy of the Bosnian model was from 93.14% to 100 %, and of the Macedonian model – from 91.18 % to 94.12 %.

Furthermore, this study points out that construction managers' information, knowledge and skills about sustainable construction practices should be advanced. Also, for the purpose of improving the sustainability in construction, managers should be informed about the factors that contribute to sustainability in construction. Managers' motivation should be increased to get a new kind of mindset in order to take a stronger effort in implementing sustainability aspects during examination of their professional duties. Also, during the construction managers licensing, more emphasis should be put on managers' knowledge and mindset of incorporating sustainability aspects in construction.

With respect to the above mentioned, the representatives of construction' industry and relevant associations have to take measures in order for the construction managers to recognize their role in sustainability of construction and their responsibility. Additionally, construction companies should invest in construction managers' training and other activities that enable conditions for construction managers dealing with the construction sustainability challenges. Also, construction companies should put more emphasis on innovations that consider sustainable aspects and the needs of future generations.

Regarding the regulation relevant for sustainability in construction, it should be noted that in B&H and in Macedonia the regulation relevant for sustainability in construction should be improved. Also, in other countries more attention should be put on sustainability in construction during the process of construction managers licensing and in sustainable construction connected regulation.

The future work should be addressed on researching more accurate predicting models for other important factors and their impact on sustainable construction. Also, the perception of other employees in construction about construction contributing factors and measures to increase their knowledge about them should be researched.

Although this investigation findings are addressed for the construction managers' perception on sustainability contributing factors in construction in the Federation of Bosnia and Herzegovina and in the R. of Macedonia they can be used as a kind of experience for other countries, and as a base or as an experience for further investigations on sustainability contributing factors in construction.

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Appendix

Table A. Questions from the questionnaire used as variables for modeling: question no. 7 is a target variable and the other questions are used as predictors

1 Number of employees in the Company:
< 10 11-20 21-50 50-25 >250
2 Working experience in years: < 2 2-5 6-10 11-20 >20
3 Previous job position / working experience:
4 Previous education: ....
5 Rank the *Construction phase* with number from 1 to 4 in your opinion, according to the attention that is given to it.
6 Rank the factor ”protection of the environment“ with number from 1 to 4 in your opinion, according to the attention that is given to it.
7 TARGET: Are you acquainted with the term *”sustainable construction”*? Yes / No
8 The project documentation for building's construction you've worked for was complete and accurate.
9 During building construction, changes occur in the project documentation.
10 During building construction, there is a substitution of building materials which are designated with the project documentation.
11 The building construction is being completed on time according to the planned schedule.
12 In the construction company certain measures are taken in prompt time related with issues as environment and workers safety.
13 During construction, there are frequent problems with payment.
14 In construction materials, selection advantage is given to their price rather to their influence onto the environment.
15 In choosing construction technology, importance is given to their price rather to the influence onto the workers or the environment.
16 Location of the buildings being constructed is appropriately chosen.
17 During construction, attention is always given to protection of the environment (taking care of the waste, pollution, noise etc.).
18 During construction, all employees pay attention to economical use of water.
19 During construction, all workers pay attention to efficient and economical use of construction materials.
20 The construction materials are ecological and recyclable.
21 During the construction, an energy resource with low impact onto the environment is being used.
22 Training for the workers is provided for application of contemporary materials and construction technologies for protection of the environment and workers' health.
23 During construction, there is an optimal use and management of human resources (workers, sub-contractors, suppliers etc.).
24 Social factors (the relations between the workers) affect the efficiency of building construction.
25 During construction, a healthy and safe working environment is provided.
26 During the construction, care is taken for the interpersonal relations among the workers.